



Climate change impact chains in tropical coastal areas

Emilia Pramova, Florie Chazarin, Bruno Locatelli, Michael Hoppe

► To cite this version:

Emilia Pramova, Florie Chazarin, Bruno Locatelli, Michael Hoppe. Climate change impact chains in tropical coastal areas. 2013. cirad-01015722

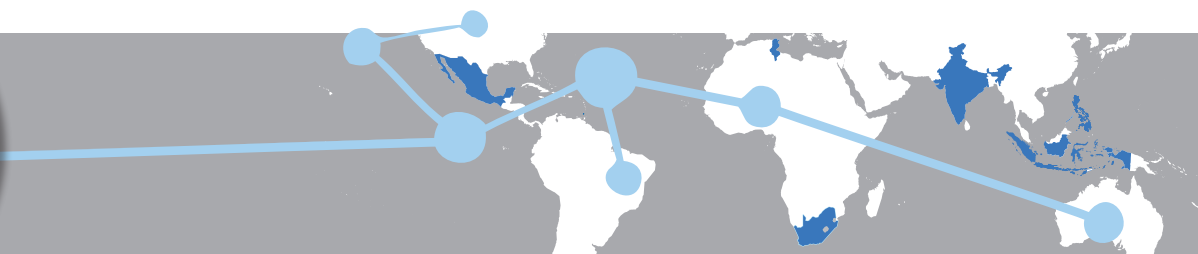
HAL Id: cirad-01015722

<http://hal.cirad.fr/cirad-01015722>

Submitted on 27 Jun 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Policy Brief

Climate change impact chains in tropical coastal areas

Tropical coasts are highly vulnerable to climatic pressures, the future impacts of which are projected to propagate through the natural and human components of coastal systems. One single event (e.g., intense storm) or gradual changes (e.g., upland deforestation or sea-level rise) can have multiple direct and indirect impacts in coral reefs, seagrass meadows, mangroves and human settlements and can compromise the resilience of the whole system.

Risks related to climate change are frequently examined in isolation through the assessment of a single economic sector or ecosystem. However, this approach may lead to the indirect impacts, mal-adaptation risks and feedback loops being overlooked. Alternatively, impact chain maps offer a way of illustrating the potential impacts of climate change in a holistic and systemic way. An impact chain represents how a pressure propagates through a system via direct and indirect impacts. This brief summarises the climate change impact chains in tropical coastal areas based on a literature review of 289 papers. Impact chains are presented for five climate-change-related pressures.

The impact chain concept is used by the Climate Impacts: Global and Regional Adaptation Support Platform ([ci:grasp](http://ci.grasp.org)) to structure climate-related information on impacts. ci:grasp is a web-based climate information service developed by the Potsdam Institute for Climate Impact Research (PIK) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). It is funded by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of its International Climate Initiative (IKI).

Ocean acidification

Ocean acidification primarily affects coral reefs and marine organisms, with subsequent effects on people and other ecosystems. It leads to changes in the marine carbonate chemistry, which can directly cause declines in coral reef calcification and growth.¹ Erosional processes might then overcome coral growth, weakening reef stability and coral competitiveness for space and light. As a result, fleshy and non-calcifying algae will dominate, damaging biodiversity and weakening the ability of reefs to recover from disturbances.²

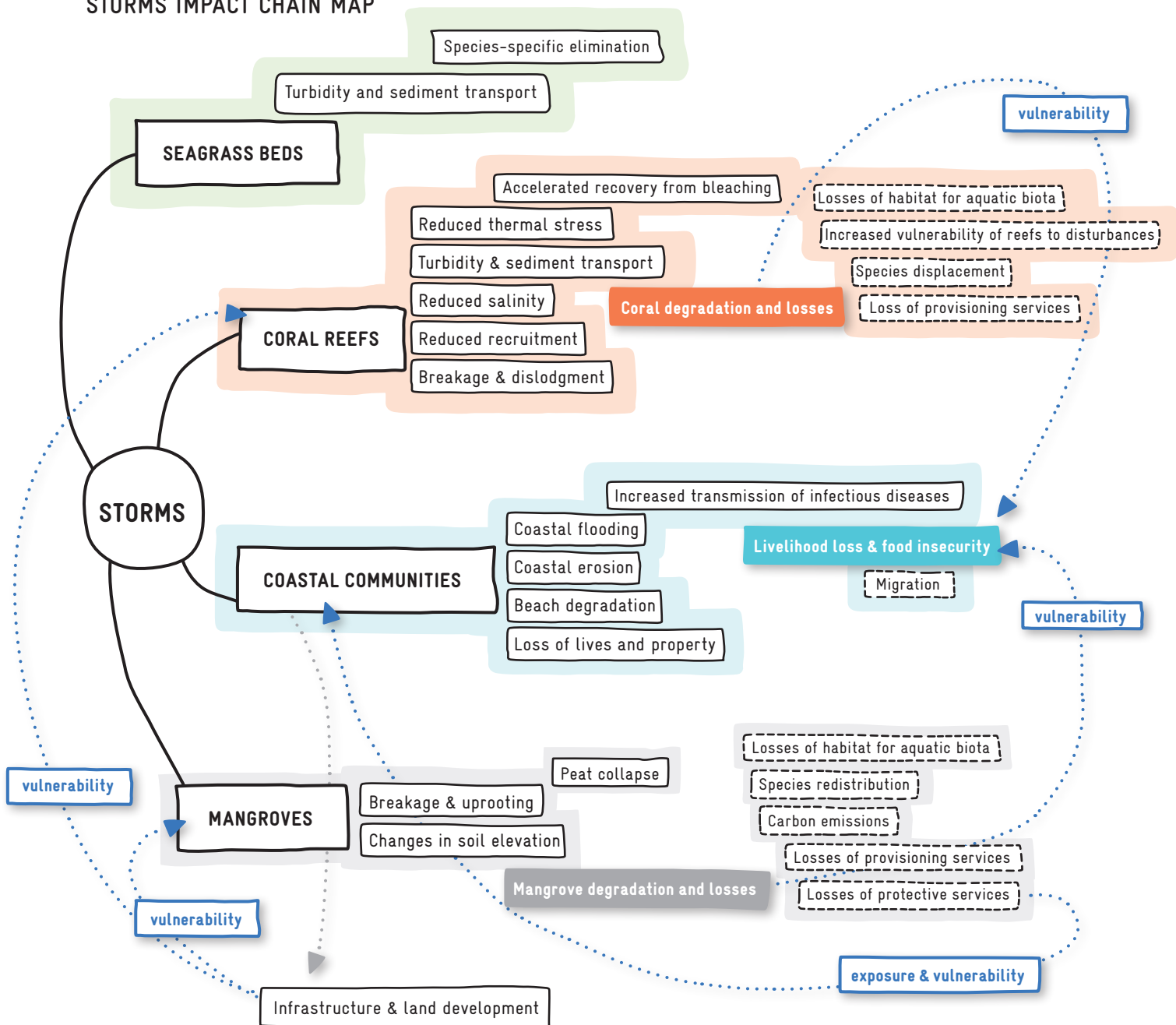
Any reef degradation and coral mortality will lead to losses in provisioning and protective (or regulating) ecosystem services.³ Coral reefs serve as breakwaters, protecting shorelines and creating quiet habitats for other ecosystems, such as mangroves and seagrass beds. They are also an important habitat for reef fish. The loss of these ecosystem services will increase the overall vulnerability of people living in coastal areas.

Acidification is projected to have a direct impact on fish communities also. Increased CO₂ dissolution in ocean waters has long-term effects on the metabolic functions, growth, and reproduction of fish, with subsequent alterations in population and species levels.² Seagrass beds, by contrast, are expected to benefit from the increased levels of CO₂ for their photosynthesis.

To slow down acidification and minimise its impacts, mitigation measures are needed to limit anthropogenic CO₂ emissions. Developing adaptation measures to minimise or delay the impacts will require additional research, such as biogeographical surveys of the range shifts of economically and ecologically critical species to adjust harvesting practices for resilience.² Either way, minimising human pressures constitutes a 'no-regrets' measure for increased resilience.²

On behalf of

STORMS IMPACT CHAIN MAP



Ocean warming and sea-surface temperature increases

Ocean warming, including increases in sea-surface temperatures, has a direct impact on reef-building corals as it decreases their growth rates⁴ and induces bleaching. For example, the 1998 ENSO events led to the bleaching of many Indian Ocean coral communities, with up to 90% mortality in shallow areas.⁵ The delayed effects of coral bleaching include predator concentration, increased bio-erosion, susceptibility to disease and parasites, and decreased capacity for wound healing.⁶

The direct socio-economic effects of bleaching on coastal communities include decreases in diving tourism⁷, declines in reef fish stocks⁸ and general losses of coral ecosystem services (e.g., regulating) because of the decline in coral cover. Coastal erosion also increases because the reefs can no longer serve as protective barriers.⁵

Declines in coral cover will reduce the habitat available for reef fish, which will also be directly affected by ocean warming because it will weaken their physiological performance and change their behaviours, especially in early life and reproduction phases.⁸ Range shifts are expected to occur for subtropical and temperate species.⁹

Fish can potentially adapt through acclimatisation over multiple generations, but this adaptation ability may be compromised by other pressures such as overfishing. Coral reefs also have the potential to adapt through the acquisition and maintenance of more thermally tolerant symbionts (algae living in symbiosis with corals).¹⁰ However, anthropogenic pressures such as nutrient enrichment and overfishing can greatly affect coral tolerance of and recovery from thermal stress.^{11, 12} Coastal management should better account for the cumulative, synergistic and mounting stresses arising from climate change and concurrent human activities.

Changes in precipitation

Decreases or increases in rainfall and associated extreme events (e.g., drought, flooding) will affect coastal areas in different ways. In mangrove ecosystems, drought could lead to increased salinity, which in turn results in growth decline, altered competition between species and the conversion of upper tidal zones to hypersaline flats.¹³ In coastal settlements, major crop losses can be expected under drought because of the lack of fresh water for irrigation, especially in small islands. Such events have already weakened food security in the South Pacific Islands.¹⁴

On the other hand, increases in rainfall (both in coastal areas and in upland areas) will have an impact not only on coastal communities and wetlands, but also on coral reefs. Inland flooding can cause sediment discharge into coral reefs, which can be detrimental to their health.¹⁵ Prolonged rainfall and flooding can also cause freshwater-induced bleaching, especially in reefs located further from the open ocean (e.g., in lagoons).¹⁶

Localised coastal flooding and inland/riverine flooding both have impacts on downstream coastal communities, as such events lead to the mass transportation of sediments and pollutants, and cause direct physical damage to settlements and agriculture.^{14, 17} Limiting pollution and sediment discharge is the first step towards reducing ecosystem and community vulnerability.

Although extreme floods can have adverse impacts on mangroves, moderate increases in rainfall can be beneficial for coastal wetlands. To minimise any negative impacts from changes in rainfall and enhance any potential positive effects, sustainable management at the broader watershed level is needed.

Sea-level rise

Sea-level rise (SLR) is one of the most certain outcomes of climate change. Relative SLR that exceeds mangrove sediment accretion and elevation is a substantial cause of recent and predicted reductions in mangrove areas and health, as it leads to sed-



iment erosion, inundation stress and increased salinity at landward zones.¹³ Even when mangroves have the possibility of migrating landwards (i.e., no barriers are present), conservation concerns are not eased, because it is the seaward fringes that provide the most valuable ecosystem services for fisheries and coastal protection.¹⁸ Any degradation or loss of mangroves will also result in substantial carbon emissions.

Accelerating SLR can also have an impact on coral reefs through increases in energy and sediment resuspension, and drowning. Sediment particles that settle on coral surfaces interfere with photosynthesis and feeding, and turbidity induced by suspended sediment reduces incident light levels.¹⁹ As mentioned above, coral reef degradation will have detrimental effects on reef fish, and subsequently on the coastal communities that depend on them for their livelihoods. Mangrove ecosystems also provide important habitats for fish and crustaceans and any losses in their extent will increase people's vulnerability. Furthermore, alterations in tidal patterns and increased turbidity and salinity will directly lead to modifications of fish habitats and, in turn, to changes in the distribution of many fish species, especially estuary species.¹⁷

Following mangrove losses, and hence the protective services they provide, coastal communities will experience the negative impacts of SLR and tropical storms more strongly. The SLR impacts of inundation and shoreline erosion have been exacerbated along many coasts in the Pacific by the clearance of coastal vegetation, the mining of sand and the construction of artificial structures that fail to take into account coastal dynamics.²⁰

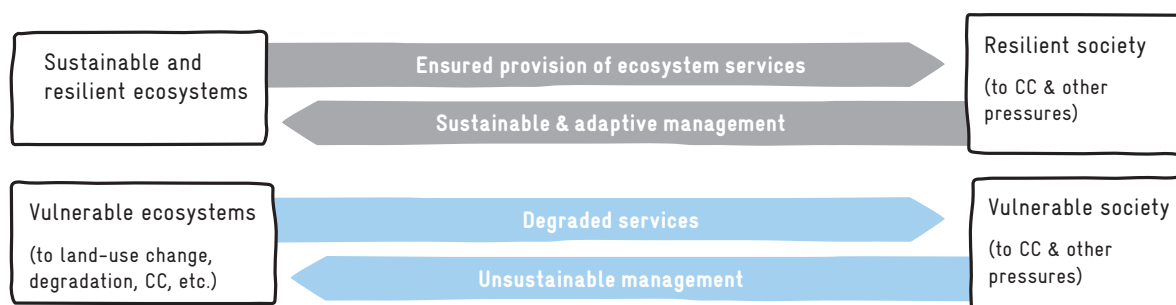
SLR will have both direct and indirect impacts on coastal settlements and agriculture. Indirect impacts are associated with the loss of ecosystem services caused by the inundation and degradation of ecosystems. Direct impacts are inundation and erosion of land, saline water intrusion and coastal flooding. The losses of land, livelihoods and property caused by SLR are projected to be significant and to force many coastal communities to migrate.²¹

Sea levels will continue to rise even under the strictest mitigation scenarios, and measures should be taken to protect coastal communities and ecosystems. However, ecosystem management should be done at the landscape level to manage sediment and other inputs that can induce further stress on coastal ecosystems. Activities can be conducted within the mangrove catchment to maintain or enhance elevation.¹³

Tropical storms

Tropical storms (e.g., cyclones, hurricanes and typhoons) first have direct impacts on both ecosystems and people, followed by cascading effects. The physical force of

ECOSYSTEM-BASED ADAPTATION



hurricanes, for example, can directly degrade and kill mangroves. By changing the space available to different species, hurricanes can also reset succession and thus alter species composition.²² Storms influence mangrove sediment elevation through soil erosion, soil deposition, peat collapse and soil compression.¹³ However, an increase in soil elevation can have a positive impact on mangrove ecosystems as it can counterbalance the effects of relative SLR.

Positive impacts can occur for coral reefs as well. At broad spatial scales, tropical cyclones can cool the upper ocean, which reduces thermal stress for bleached corals and accelerates their recovery. Moderate storms can transfer sediment particles that uplift reef layers without breaking the corals²³ and can aid larvae dispersal from and onto reefs. Strong storms, however, induce physical damage through breakage and dislodgement, adversely affect coral recruitment and reduce salinity levels to points that can be lethal.²⁴ They also cause large sediment blowouts that can clear seagrass meadows, leading to long-term effects such as the colonisation of the cleared space by macroalgae.²⁵

Again, degradation and losses in ecosystems affect coastal communities through the loss of ecosystem services. The loss of storm-protection services of mangroves, for example, renders people progressively more vulnerable to climate stressors. By contrast, settlements protected by mangrove ecosystems have been shown to suffer significantly less damage during past cyclone events than unprotected ones.^{26, 27}

As climate change progresses, tropical storms are predicted to become more intense and frequent. In the absence of coastal protection, direct impacts such as coastal flooding, erosion and beach degradation will become even more severe, as will the loss of life, property and livelihoods. In addition to ecosystem conservation activities, actions must be taken to minimise disaster risk. Such actions include constructing or modernising early warning systems, developing shelters and evacuation plans, constructing coastal embankments, raising awareness at the community level, mapping high-risk areas, and establishing and enforcing appropriate building codes.²⁸

Conclusion

Impact chain maps can improve understanding of the direct and indirect effects that can be triggered by climate-related pressures at different levels in socio-ecological systems. However, whereas the maps illustrate potential impacts, the actual impacts will depend on specific socio-economic and ecological factors, such as disaster preparedness and geomorphology. In addition, decision making for adaptation should take into account the effects of multiple interacting stressors.

Nevertheless, impact chains make it apparent that the resilience of each system component is interconnected: the more resilient the ecosystems, the greater the resilience and adaptation of the people that depend on them. In turn, people must manage ecosystems appropriately to ensure their resilience and the ongoing delivery of important ecosystem services, as degraded ecosystems are more vulnerable to stressors and recover more slowly (if at all) after a disturbance.

Ecosystem-based adaptation, defined as the use of biodiversity and ecosystem services to help people to adapt to climate change, offers one approach for achieving this, if planned and implemented appropriately and according to local conditions. However, it should be supplemented by additional measures such as preparedness activities (e.g., early warning systems), infrastructural measures and capacity building.

Download the full study report "[Climate Change Impact Chains in Coastal Areas \(ICCA\)](#)" and the [Annex](#).

Access the individual impact chain maps on [ci:grasp](#):

- [Ocean acidification](#)
- [Ocean warming](#)
- [Changes in precipitation](#)
- [Sea-level rise](#)
- [Tropical storms](#)

References

- 1 Shaw, E.C., McNeil, B.I., Tilbrook, B., 2012. Impacts of ocean acidification in naturally variable coral reef flat ecosystems. *Journal of Geophysical Research: Oceans* (1978–2012) 117.
- 2 Guinotte, J.M., Fabry, V.J., 2008. Ocean acidification and its potential effects on marine ecosystems. *Annals of the New York Academy of Sciences* 1134, 320–342.
- 3 Kleypas, J.A., Yates, K.K., 2009. Coral reefs and ocean acidification. *Oceanography* 22, 108–117.
- 4 Cantin, N.E., Cohen, A.L., Karnauskas, K.B., Tarrant, A.M., McCorkle, D.C., 2010. Ocean warming slows coral growth in the central Red Sea. *Science* 329, 322–325.
- 5 Wilkinson, C., Lindén, O., Cesar, H., Hodgson, G., Rubens, J., Strong, A.E., 1999. Ecological and socioeconomic impacts of 1998 coral mortality in the Indian Ocean: an ENSO impact and a warning of future change? *Ambio* 28.
- 6 Glynn, P.W., Mate, J.L., Baker, A.C., Calderon, M.O., 2001. Coral bleaching and mortality in Panama and Ecuador during the 1997–1998 El Niño–Southern Oscillation event: spatial/temporal patterns and comparisons with the 1982–1983 event. *Bulletin of Marine Science* 69, 79–109.
- 7 Zeppel, H., 2012. Climate change and tourism in the Great Barrier Reef Marine Park. *Current Issues in Tourism* 15, 287–292.
- 8 Munday, P.L., Jones, G.P., Pratchett, M.S., Williams, A.J., 2008. Climate change and the future for coral reef fishes. *Fish and Fisheries* 9, 261–285.
- 9 Lloyd, P., Plaganyi, E.E., Weeks, S.J., Magno-Canto, M., Plaganyi, G., 2012. Ocean warming alters species abundance patterns and increases species diversity in an African sub-tropical reef-fish community. *Fisheries Oceanography* 21, 78–94.
- 10 Baker, A.C., Starger, C.J., McClanahan, T.R., Glynn, P.W., 2004. Coral reefs: corals' adaptive response to climate change. *Nature* 430, 741–741.
- 11 McClanahan, T., 2008. Response of the coral reef benthos and herbivory to fishery closure management and the 1998 ENSO disturbance. *Oecologia* 155, 169–177.
- 12 Wooldridge, S.A., Done, T.J., Thomas, C.R., Gordon, I.I., Marshall, P.A., Jones, R.N., 2012. Safeguarding coastal coral communities on the central Great Barrier Reef (Australia) against climate change: realizable local and global actions. *Climatic Change* 112, 945–961.
- 13 Gilman, E.L., Ellison, J., Duke, N.C., Field, C., 2008. Threats to mangroves from climate change and adaptation options: a review. *Aquatic Botany* 89, 237–250.
- 14 Barnett, J., 2011. Dangerous climate change in the Pacific Islands: food production and food security. *Regional Environmental Change* 11, 229–237.
- 15 Pereira, M.A., Gonçalves, P.M.B., 2004. Effects of the 2000 southern Mozambique floods on a marginal coral community: the case at Xai-Xai. *African Journal of Aquatic Science* 29, 113–116.
- 16 Perry, C.T., 2003. Reef development at Inhaca Island, Mozambique: coral communities and impacts of the 1999/2000 southern African floods. *AMBIO: A Journal of the Human Environment* 32, 134–139.
- 17 Martínez Arroyo, A., Manzanilla Naim, S., Zavala Hidalgo, J., 2011. Vulnerability to climate change of marine and coastal fisheries in México. *Atmósfera* 24, 103–123.
- 18 López-Medellín, X., Ezcurra, E., González-Abraham, C., Hak, J., Santiago, L.S., Sickman, J.O., 2011. Oceanographic anomalies and sea-level rise drive mangroves inland in the Pacific coast of Mexico. *Journal of Vegetation Science* 22, 143–151.
- 19 Ogston, A.S., Field, M.E., 2010. Predictions of turbidity due to enhanced sediment resuspension resulting from sea-level rise on a fringing coral reef: evidence from Molokai, Hawaii. *Journal of Coastal Research* 26, 1027–1037.
- 20 Nunn, P.D., Mimura, N., 1997. Vulnerability of South Pacific island nations to sea-level rise. *Journal of Coastal Research* 133–151.
- 21 Wetzel, F.T., Kissling, W.D., Beissmann, H., Penn, D.J., 2012. Future climate change driven sea-level rise: secondary consequences from human displacement for island biodiversity. *Global Change Biology* 18, 2707–2719.
- 22 Piou, C., Feller, I.C., Berger, U., Chi, F., 2006. Zonation patterns of Belizean offshore mangrove forests 41 years after a catastrophic hurricane. *Biotropica* 38, 365–374.
- 23 Lugo-Fernandez, A., Gravois, M., 2010. Understanding impacts of tropical storms and hurricanes on submerged bank reefs and coral communities in the northwestern Gulf of Mexico. *Continental Shelf Research* 30, 1226–1240.
- 24 Van Woesik, R., 1994. Contemporary disturbances to coral communities of the Great Barrier Reef. *Journal of Coastal Research* 12, 233–252.
- 25 Van Tussenbroek, B.I., Barba Santos, M.G., Van Dijk, J.K., Sanabria Alcaraz, S.M., Téllez Calderón, M.L., 2008. Selective elimination of rooted plants from a tropical seagrass bed in a back-reef lagoon: a hypothesis tested by Hurricane Wilma (2005). *Journal of Coastal Research* 24, 278–281.
- 26 Badola, R., Hussain, S., 2005. Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation* 32, 85–92.
- 27 Das, S., Vincent, J.R., 2009. Mangroves protected villages and reduced death toll during Indian super cyclone. *Proceedings of the National Academy of Sciences of the United States of America* 106, 7357–7360.
- 28 Haque, U., Hashizume, M., Kolivras, K.N., Overgaard, H.J., Das, B., Yamamoto, T., 2012. Reduced death rates from cyclones in Bangladesh: what more needs to be done? *Bulletin of the World Health Organization* 90, 150–156.

For more information please contact us.



Edited by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Inventory of Methods for Adaptation
to Climate Change – IMACC
Dag-Hammarskjöld-Weg 1–5
65760 Eschborn, Germany
T +49 6196 79 – 0
F +49 6196 79 – 1115
E info@giz.de
I www.giz.de/climate

Contact
Michael Hoppe
michael.hoppe@giz.de
Nele Bünner
nele.buenner@giz.de

Authors
Emilia Pramova, Florie Chazarin (CIFOR Indonesia)
Bruno Locatelli (CIFOR Indonesia, CIRAD France)
Michael Hoppe (GIZ Germany)

November 2013